European Archives of Oto-Rhino-Laryngology (2023) 280:1919–1926
https://doi.org/10.1007/s00405-022-07744-6

HEAD AND NECK

Evaluation of a questionnaire as a screening tool for benign paroxysmal position vertigo

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Received: 17 September 2022 / Accepted: 7 November 2022 / Published online: 24 November 2022

Abstract

Objective To determine the value of a questionnaire as a screening tool for benign paroxysmal position vertigo (BPPV).

Study design Retrospective chart review.

Setting Tertiary care centers.

Methods A total of 520 vertigo adults completed the questionnaire before the diagnosis was confirmed. After vestibular function examination and other diagnostic examination, the diagnosis of all participants was confirmed by experts. By validating valuable items from the questionnaire with 47 items, a new questionnaire of 5 items was formed to quickly diagnose BPPV. The internal consistency of the new questionnaire and validity were evaluated. The correlation between the score obtained from the new questionnaire and diagnosis was investigated. The mean score was also compared between groups with and without BPPV and diagnostic precision measures were calculated.

Results 520 vertigo participants answered all the question completely and BPPV was identified in 138 participants (26.5%). The responses to questionnaire revealed preferable reproducibility ($r = 0.898$, $P < 0.05$) and internal consistency (Cronbach's $\alpha = 0.702$) as well as the validity (Kaiser–Meyer–Olkin, KMO = 0.731). The higher the individual score, the more likely to be BPPV ($B = 2.082$; $P < 0.05$). The mean score of answers was greater in the group with a clinical diagnosis of BPPV compared to those without BPPV ($F = 58.459$, $P < 0.05$). The sensitivity of the screening tool was 92.8% and specificity was 88.5%, with an area under the ROC curve of 0.946 (95% confidence interval 0.926–0.965; $P < 0.05$).

Conclusion The questionnaire proved to be of great value to screen for individuals with possible BPPV.

Keywords Benign paroxysmal position vertigo · Questionnaire · Screening

Introduction

Benign paroxysmal positional vertigo (BPPV) is a clinical disease common in patients with vertigo or dizziness. An epidemiological study of the German adult population by von Brevern et al. showed a lifetime prevalence of 3.2% in women, 1.6% in men, and the annual incidence is 0.6%.; The incidence of female is twice of male [1]. The study also revealed the incidence increases with age [2]. According to a recent systematic review, BPPV accounted for 16.3% of outpatients with dizziness [3]. Besides, the recurrence rate varies in different articles. The recurrence rate within 1 year is 7 to 23%, and the long-term recurrence rate reach up to 50% [4], especially in elderly women [5]. BPPV can typically be diagnosed by a positional test, but is poorly recognized by the general public.

The clinical manifestations of BPPV are transient vertigo, nausea, imbalance, and positional nystagmus with a change

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in head position [6]. Including idiopathic and secondary, the latter can be caused by systemic or related ear diseases, such as head trauma, abnormal calcium metabolism, and inner ear diseases [7–10]. According to previous study that ischemia in internal ear was also responsible for BPPV [11]. Its incidence is very different, accounting for about 3.0–25.2% [12]. It may be related to the posture during bed rest [13]. BPPV is caused by otoconia falling off the otolith macula bed of utricle or saccule and floating freely in the semicircular canal or adhering to the cupula [14]. However, its exact etiology is unknown, and, in most cases, cannot be identified.

The International Classification of Vestibular Disorders (ICVD) includes typical diagnostic criteria for BPPV, including canalolithiasis of posterior semicircular canal (PC), canalolithiasis of horizontal canal (HC), cupulolithiasis of horizontal canal, as well as the newly emerging and controversial canalolithiasis of anterior canal (AC) and cupulolithiasis of PC [2]. Position tests include vertigo and nystagmus stimulation, and different maneuvers test different semicircular canals. The canal-specific reaction is diagnosed when the maximum intensity of positional nystagmus is caused by head rotation in the semicircular canal plane. On account of the position test needs appropriate requirements for the operation of the receiving physician, a lot of BPPV can be misdiagnosed as other diseases. In this study, BPPV rapid diagnosis questionnaire was developed to improve the efficient screening of BPPV for the community physicians.

Materials and methods

Study design

The data of vertigo patients treated in the Eye & ENT Hospital of Fudan University and The Second Affiliated Hospital of Anhui Medical University from August 2020 to December 2021 was collected. Through reading professional books and literature reviews and consulting experts, the questionnaire including 47 items such as age, gender, vertigo-related symptoms, inducement and other medical history was developed. All individuals completed the 47 items questionnaire before definitive diagnosis. After vestibular function examination including positional tests, audiology test and imaging examination, the final diagnosis of vertigo for each patient was determined by at least 2 clinical experts with more than 5 years of experience in the field and senior professional title based on the examination results and reference to the related diagnosis and treatment guidelines. After diagnosis, 520 participants were divided into BPPV group and No-BPPV group. Through binary logistic analysis, the influencing factors associated with the diagnosis of BPPV were extracted from the 47 items questionnaire and reconstructed a new questionnaire with 5 items. The 5 items were as follows: (i) The head spins or the object spins; (ii) Duration of dizziness $\leq$ 1 min; (iii) Vertigo occurs when rising from a decubitus position or lying down suddenly; (iv) Vertigo occurs when turning over in decubitus position; (v) Symptoms disappear when keeping head position. Although gender was also an influencing factor, it has a poor correlation with other factors through factor analysis. Thus, the new questionnaire excluded gender. The first data of the new questionnaire come from the questionnaire with 47 items. One week after the first visit, all patients were revisited and completed the new questionnaire secondly. To evaluate the reproducibility, the results of the two new questionnaires were calculated. All data analyses were performed using the new questionnaire data from the first time.

Furthermore, the new questionnaire was analyzed and evaluated by statistical methods. In the new questionnaire, individuals answered "yes" or "no" to each question. "Yes" is worth 1 point, "no" is worth 0 points. Finally, the total scores were obtained, and the relationship between total scores and BPPV was studied.

Inclusion and exclusion criteria

Inclusion criteria: The chief complaint is dizziness or vertigo; Adults over the age of 18; Agree to participate in this study. Exclusion criteria: serious cardiovascular and cerebrovascular diseases, unable to cooperate with inspection, and Unable to complete the questionnaire.

Analysis of the new questionnaire as a screening tool for BPPV

The reliability of the questionnaire was determined by reliability reproducibility and internal consistency. All participants completed the new questionnaire again 1 week later. Reproducibility was assessed by comparing the results of the new questionnaire before and after 1 week [15]. All data analyses were performed using the results of the first new questionnaire. Internal consistency mainly reflects whether the same content can be measured among the items of questionnaire. In other words, it measures the homogeneity of multiple indicators of the same concept. The internal consistency of the questionnaire was represented by the Cronbach's alpha coefficient, with Cronbach's $\alpha \geq 0.7$, regarded as highly reliable.

Validity analysis composed of content and structure referred to the degree of validity or practicability of a questionnaire. The part of content was assessed by two experts that the questionnaire was reasonable; the content was satisfactory. The KMO (Kaiser–Meyer–Olkin) result and Bartlett's test was calculated by factor analysis

evaluating the structure part. The cumulative contribution rate of more than 70% was considered satisfactory [16].

The total scores of new questionnaires with BPPV and without BPPV were calculated. Comparing various cutoff points to confirm the best cutoff point, the sensitivity and specificity of the questionnaire were determined by the receiver operating characteristic (ROC) curves. On the foundation of the scores, the area under the ROC curve (AUC), the sensitivity, specificity were analyzed. The AUC above 0.9 indicated excellent accuracy [17].

Furthermore, the total score and mean score of the questionnaire were compared between the groups of individuals with and without a diagnosis of BPPV. And the association analysis between each item in the questionnaire and the diagnosis of BPPV was performed with Pearson's chi-square test. Meanwhile, the clinical characteristics in the BPPV group were analyzed.

Statistics

The influence items of BPPV are obtained by binary logistic analysis. A Pearson's chi-square test was used to study the distribution of the related items in different groups. And independent-samples *T* test was used to analyze the scores of different groups. Statistical tool SPSS 21.1 was used for all statistical evaluation. Significance was set at $P < 0.05$.

Declarations

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The project, led by Eye & ENT Hospital of Fudan University(certificate number: 2019091) and The Second Affiliated Hospital of Anhui Medical University(SLYX2020-058 (F1), has received ethical approval.

Results

Characteristics of sample

A total of 520 participants completed 47 items in the questionnaire before the diagnosis was confirmed. Female dominated the survey ($n = 305$; 59%). All participants were 18–85 years old. The largest age group was those 35 years old to 59 years old ($n = 272$; 52%). The mean age of patients in the study was 50.81 ± 14.05 years old. The largest distribution of vertigo was BPPV ($n = 138$; 27%). Table 1 showed the characteristics of sample.

Table 1 Characteristics of the sample

Variables	Options	*n*	%
Gender	Male	215	41
	Female	305	59
Age groups	18–34 years	79	15
	35–59 years	272	52
	≥ 60 years	169	33
Diagnosis	PPPD	35	6.7
	SCD	23	4.4
	CV; VV	5	1.0
	BPPV	138	26.5
	PV	10	1.9
	MD	67	12.9
	VD	28	5.4
	VN	19	3.7
	VM	130	25.0
	ISD	65	12.5

PPPD persistent postural-perceptual dizziness, *SCD* semicircular canal dehiscence, *CV* cervical vertigo, *VV* vascular vertigo, *PV* psychogenic vertigo, *MD* Meniere's disease, *VD* vestibular dysfunction, *VN* vestibular neuritis, *VM* vestibular migraine, *ISD* idiopathic sudden deafness

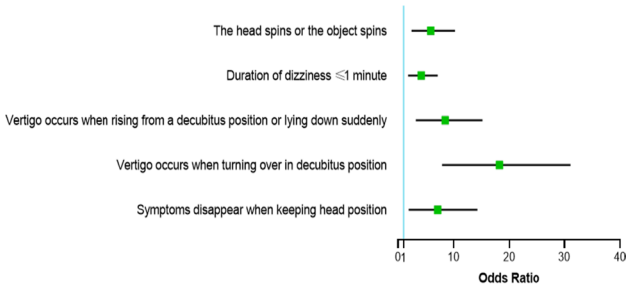

Fig. 1 The results of Logistic analyze and composition of the new questionnaire ($P < 0.05$)

Composition of the new questionnaire

Figure 1 showed the five items of the new questionnaire. After logistic analysis, the five items in Fig. 1 was associated with the diagnosis of BPPV. Although the Odds Ratio (OR) (95%CI) of male and female was 0.29 (0.15–0.57), $P < 0.05$, gender has a poor correlation with other 5 items. Thus, it was not included in the new questionnaire as a screening standard for BPPV.

Table 2 The results of extracting three factors

Factors	Eigenvalue	Contribution (%)	Cumulative contribution (%)
1	1.655	33.107	33.107
2	1.283	25.666	58.773
3	1.005	20.104	78.877
4			
5			

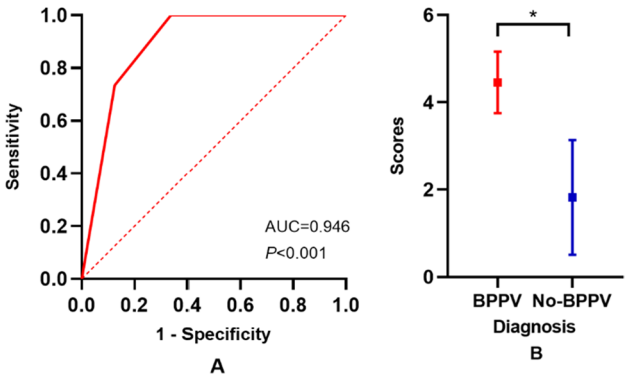

Fig. 2 **A** showed the ROC of scores of the new questionnaire. **B** showed scores of the new questionnaire was significantly higher among the participants diagnosed with BPPV than those without BPPV (* means $P<0.05$)

Reliability and validity

The total score of the new questionnaire was five points, with one point for each item, compared to the same item a week ago. After correlation analysis, the difference was significant ($r=0.898$, $P<0.05$), which demonstrated satisfactory reproducibility produced by the questionnaire. The Cronbach's $\alpha=0.702$, indicating that the questionnaire is reliable. Factor analysis was performed on the new questionnaire scores of all participants, the KMO coefficient was 0.731 and Bartlett's Test of sphericity showed significant difference ($P<0.05$), which mean the five items were suitable for factor analysis. The cumulative contribution rate was 78.88% by extracting three factors. Table 2 displayed factors and cumulative contribution rate.

Accuracy

The new questionnaire has a range of scores from 0 to 5. According to the ROC curve, the AUC was 0.946(95% CI 0.926–0.965; $P<0.05$), meaning that the scores of the new questionnaire was significant for the diagnosis of BPPV (Fig. 2). Table 3 displayed the indicators of questionnaire for epidemiological screening of BPPV using different cutoff points. A score of 3.5 points was the best cutoff point, meaning that scores ≥ 3.5 points, diagnosis was significant. The sensitivity was 92.80%, specificity was 88.50%. Figure 2 showed that the scores of the new questionnaire was significantly higher among the participants diagnosed with BPPV (mean 4.46; SD 0.71) compared to those without BPPV (mean 1.82; SD 1.31; $P<0.05$, independent-samples T test).

Table 3 Indicators of questionnaire for epidemiological screening of BPPV using different cutoff points

Cutoff point	Sensitivity (%)	Specificity (%)	Youden's index
0.50	100.00	17.00	0.170
1.50	99.30	45.80	0.451
2.50	98.60	69.10	0.677
3.50	92.80	88.50	0.812
4.50	55.10	97.40	0.525

Difference between groups with BPPV and without BPPV

Table 4 showed the distribution of gender in the group with BPPV and without BPPV. This distribution was also illustrated in Fig. 3. Gender was correlated with the diagnosis of BPPV ($\chi^2=4.87$; $P<0.05$). The number of female was more than male in the diagnosis of BPPV. Age did not affect the distribution of BPPV. The distribution of other factors was displayed in Fig. 3. The distribution of question I to V between BPPV and No-BPPV was significantly different ($P<0.05$). The positive symptoms of I-V were associated with the diagnosis of BPPV. The proportion of positive symptoms in BPPV group was higher than that of negative symptoms. Besides, the proportion of positive symptoms in BPPV group was higher than that in No-BPPV group.

Discussion

BPPV is regarded as the most common cause of peripheral vertigo, a kind of peripheral disease induced by changes in the direction of head position relative to gravity, characterized by the transient onset of intense vertigo and nystagmus, which is self-limited and prone to recurrence, often accompanied with nausea and vomiting [6]. The calcium carbonate particles in the utricular otolith membrane are displaced into the semicircular canal or adhered to the cupula. As the position changes with respect to gravity, these particles move to different positions in the semicircular canal, exciting the vestibular nerve that innervates this semicircular canal, with conduction of the exciting electric activity signal, which was projected to oculomotor nucleus, causing the eye muscle contraction, the nystagmus, vertigo, vomiting and other

Table 4 Distribution of gender and age in the group with BPPV

Variables	BPPV		*P*
	Yes	No	
Gender			
Male	68	147	0.027
Female	70	235	
Age			
18–34 years	17	62	0.710
35–59 years	77	195	
≥ 60 years	44	125	

clinical symptoms [18]. In adults, the prevalence rate is 2.4% and increases with age [19]. Some studies shows that BPPV was associated with the increased exposure to anxiety disorders, depression and falls [20, 21]. There were also reports suggested that the incidence of BPPV had a great relationship with osteoporosis [22, 23].

On the fundament of clinical history, the diagnosis of BPPV was determined by the presence of nystagmus and vertigo during postural movements or after the latent period of a few seconds. It can be transient and fatigued. Depending on the symptoms caused by the change in head position with the Dix–Hallpike test or roll test, the affected semicircular canals can be identified. After appropriate reposition of the head, the symptoms in patients diagnosed as BPPV relieved apparently [24]. However, both domestic and foreign research as well as clinical work have reported that BPPV was easily misdiagnosed as other diseases, resulting in a low primary diagnosis rate of this disease.

According to previous study, Kim et.al came up with a questionnaire for BPPV, which includes 6 questions. Though the accuracy of diagnosis for BPPV is acceptable, some limitations are still exit. First, the questionnaire is not suitable for acute patients, which is based on referral patients with BVVP. Then, it needs be further improved for the canal/subtype of BPPV. Besides, it lacks of validation of the questionnaire in the second sample [25]. Britt et.al study linear predictor (LP) value in diagnosing BVVP based on questionnaire. This questionnaire prove that LP is a good predictor for BVVP. However, it is difficult to differentiate between vertigo episodes that lasted seconds to minutes from those that lasted minutes to hours because this was not always accurately recorded [26]. At present, there is a lack of diagnostic questionnaire for BPPV in China. Therefore, to improve the discriminative ability of this disease, this study analyzed the clinical symptoms of BPPV, extracted valuable questionnaire items, and passed expert discussion. The BPPV rapid screening questionnaire was finally developed.

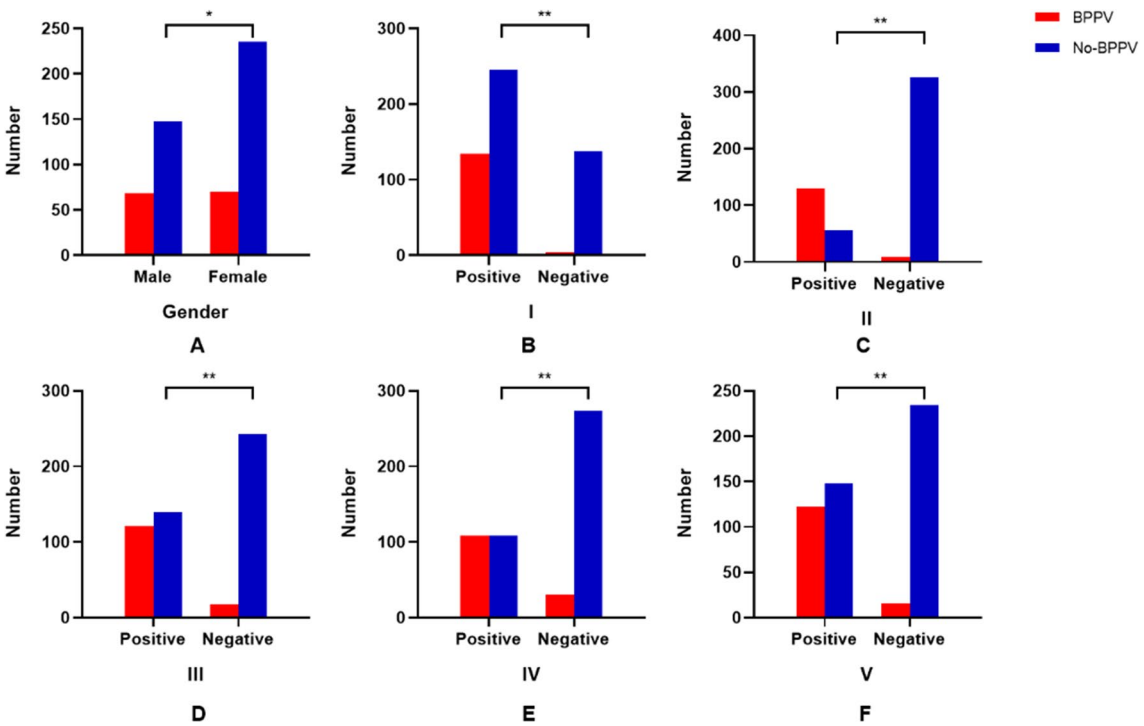

Fig. 3 **A** showed distribution of gender in different groups; **B–F** showed the distribution of items from I to V in the new questionnaire (* means $P < 0.05$; ** means $P < 0.01$). (I) The head spins or the object spins; (II) Duration of dizziness ≤ 1 min; (III) Vertigo occurs when rising from a decubitus position or lying down suddenly; (IV) Vertigo occurs when turning over in decubitus position; (V) Symptoms disappear when keeping head position

According to Cronbach's coefficient (0.702), the questionnaire suggested satisfactory reliability. The KMO value (0.731) and Bartlett's Test of sphericity ($P < 0.05$), meant the five items of the new questionnaire were suitable for factor analysis. The cumulative contribution was 78.88%, proving that the questionnaire had satisfying structural validity. And based on Youden's index and the area under the ROC curve (AUC), we discovered that the questionnaire has good sensitivity and specificity. Therefore, this questionnaire was applicable for the diagnosis of BPPV as a screening tool [27]. Comparison of the score between BPPV and No-BPPV groups demonstrated that patients with higher scores on the questionnaire were more likely to be diagnosed as BPPV.

In the analysis of each item on the new questionnaire and the diagnosis of BPPV, the items from I to V proved to be associated with the diagnosis from Fig. 3. Compared with the No-BPPV group, the vertigo in BPPV group was more likely to occur when rising from a decubitus position, lying down suddenly or turning over. Besides, they had a sense the head spun or the object spun around the earth, but the duration was less than 1 min and symptoms disappeared when keeping head position. The results of these items differed significantly between the BPPV and No-BPPV groups, indicating that these symptoms were of great significance for the diagnosis of BPPV. Agreed with previous study [28], our study found that the prevalence of BPPV in female was higher than in male, which was related with lower Vitamin D level in women [29, 30]. According to some researches, studies have measured the relationship between Ca-related disease and BPPV, on account of that Ca channel proteins related to vitamin D in the epithelium are present in the Ca metabolism of the vestibular organ [31, 32]. The mechanism of BPPV was regarded as that macula of the utricle or saccule and slid in the semicircular canal or adhered to the cupula. $CaCO_3$ and glycoprotein crystals were the main components of otoconia and the crystals were surrounded by inorganic peripheral areas with minerals which is mainly composed of $CaCO_3$ with high Ca levels [33]. Osteoporosis and vitamin D deficiency were very common in general, but, it's rare in BPPV patients with osteoporosis with vitamin D deficiency [34]. However, another study expressed that Vitamin D deficiency and low ionized calcium could cause BPPV not only in patients with osteoporosis, but in all patients [35].Furthermore, some studies reported that Vitamin D levels on individuals with BPPV were lower than those participants diagnosed without BPPV, and some cases have shown severe vitamin D deficiency in patients had a higher recurrence rate of BPPV [36–38]. Promotion on vitamin D deficiency in BPPV had an additional benefit on the duration of improvement in rehabilitation therapy (Epley maneuver) and at the same time, the promotion was associated with a significant reduction in recurrence of BPPV [39, 40]. The reason why women in the BPPV had lower vitamin D levels than men was possibly that the levels of sunlight that women were exposed to were lower than men due to their traditional style of dressing.

Some studies reported age correlated with recurrence rate, with age increasing, recurrence rate rising [41–43]. The elderly were more likely to suffer from hypertension, diabetes and vascular diseases. Glucose metabolism was related with a high incidence of inner ear disorders, including occurrence and recurrence of BPPV [44]. A large number of studies have shown that BPPV was associated with high risk factors of cardiovascular disease possibly [45, 46]. However, in this study, there were more patients suffering from BPPV under 60 years old than those over 60 years, which was different from previous studies [47]. The reason may be that older patients with vertigo are worried about the symptoms caused by acute stage of cardiovascular and cerebrovascular diseases, so they first consult the neurology department, due to the lack of recognition of the disease. When acute symptoms were treated symptomatically and the symptoms alleviated, they may be misdiagnosed as other diseases. In addition, this was a single center study, and the diversity of the sample was limited, resulting in an unbalanced distribution of ages. In the future, it's preferable to enlarge sample and perform multicenter study for further research. However, an increasing number of young people suffering from BPPV reminded us to take action to prevent it necessarily.

Conclusion

The questionnaire proved to be of great value to screen for individuals with possible BPPV. Furthermore, the rapid diagnosis questionnaire was developed to improve the efficient screening of BPPV for the community physicians.

Limitation

The limitation of our study was a retrospective design, which limited the adequate information of patients participating in the study. The sample capacity was not sufficient to analyze and discuss the applicability of the questionnaire comprehensively.

Acknowledgements We would like to thank all participants for their time during this study.

Author contributions LY, contributed to data collection, statistical analysis, manuscript writing and editing and approved the final submission; XW, contributed to data collection, statistical analysis, manuscript editing, and approved the final submission; ZW, collected data, contributed data and analysis tools; JY, contributed to the formulation of the research idea, data collection, statistical analysis, manuscript writing and editing, and approved the final submission.

Funding The study was supported by funding from the National Natural Science Foundation of China [nos. 82071055].

Data availability The data used to support the findings of this study are available on request to the corresponding author: Jianming Yang, Email: Jmingyang88@163.com.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest.

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